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The Fermi Paradox in the light of the Inflationary and Brane World Cosmologies

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ABSTRACT

The Fermi Paradox is discussed in the light of the inflationary and brane world cosmologies. We conclude that some brane world cosmologies may be of relevance for the problem of civilizations spreading across our galaxy, strengthening the Fermi Paradox, but not the inflationary cosmologies, as has been proposed.

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1 The Fermi Paradox

Los Alamos, summer 1950. At lunch Enrico Fermi, Edward Teller and other colleagues bring up the subject of unidentified flying objects, which was very popular at that time. After a while, when they had changed subjects Fermi suddenly asked: Where is everybody? Performing fast mental computations, Fermi had reached the conclusion that alien civilizations should have been around visiting Earth for many thousands or millions of years. Therefore, why we do not see them? This is the Fermi Paradox.

Although Fermi never explained how he made his computations, nor gave an estimate of the number of civilizations which should have visited Earth, he had to rely on arguments like these: In our galaxy there are thousands of millions of stars much older than the Sun, many of them thousands of millions of years older (in the 'habitable zone' of the galaxy they are on average one thousand million years older [1]). Therefore many civilizations must have arisen in our galaxy before ours and a fraction of them must have expanded through large regions of the galaxy or even through the entire galaxy.

Some other arguments that probably were not available at that time involve estimates about the lifetime of the second generation stars, inside of which the chemical elements of organic matter are made, and also involve estimates of the total time necessary for a technological civilization to colonize, or visit, the whole galaxy. Regarding the second generation stars, they are formed only two million years after the supermassive first generation stars. The reason is that supermassive stars burn out completely exploding as supernovae in one million years only and it takes another million years for the debris to form new stars. Therefore the appearance of organic matter in our galaxy could have happened several thousands of millions of years before the Sun came into existence. As to the total time necessary to colonize, or visit, the whole galaxy by a technological civilization, conservative computations of diffusion modeling give estimates from 5 to 50 million years [2], which is a cosmologically short timescale. Besides these considerations, the fact that life on Earth started very early supports the views, held by many scientists, that life should be abundant in the Universe.

2 Solutions to the Fermi Paradox

Many solutions have been proposed to the Fermi paradox. We classify them as expansionist and non-expansionist, depending on whether they rely on the idea that technological civilizations expand or do not expand through large regions of the galaxy. The most popular non-expansionist solutions, based on the assumption that technological

civilizations do not expand beyond a small neighborhood, are the following ones:

- Interstellar travel is not possible no matter the scientific and technological level reached by a civilization. Advocates of this idea are, for example, most experts of the SETI (Search for Extraterrestrial Intelligence) project, who for about 30 years are trying to detect electromagnetic signals from distant civilizations.
- Generically, advanced civilizations have little or no interest in expanding through large regions of the galaxy.
- Technological civilizations annihilate themselves, or disappear by natural catastrophes, before having the chance to spread through large regions of the galaxy.

On the other hand, the most popular expansionist solutions to the Fermi Paradox, based on the assumption that generically technological civilizations (or a non-negligible fraction of them) do expand through large regions of the galaxy, are the following ones:

- Alien civilizations do visit Earth at present times, for different purposes, and/or have visited Earth in the past. In this respect it is remarkable the fact that Francis Crick, one of the discoverers of the DNA structure, proposed in the mid-seventies that life on Earth could have been inseminated on purpose by alien intelligences intelligences*. Besides, some scientists as well as many authors of popular books, have speculated that some unidentified flying objects could be true alien spacecrafts whereas some 'gods' descending from the sky, abundant in many ancient traditions, could have been just alien astronauts (see for example [3]).
- Advanced alien civilizations have not encountered the Solar System yet, but they are on their way.
- Advanced alien civilizations might have strong ethical codes against interfering with primitive life-forms [4].
- Advanced aliens ignore us because of lack of interest due to our low primitive level. For example Robert Jastrow, ex-director of Mt. Wilson Observatory, claims [5] that, in average, advanced civilizations should consider us as larvae due to the fact that they should be thousands of millions of years ahead of us.... and who would be interested in communicating with larvae?

*It is less known that several years before Crick, in 1960, the astronomer Thomas Gold suggested, during a congress in Los Angeles, that space travellers could have brought life to Earth some thousands of millions of years ago.

- Alien civilizations have not reached us yet because intelligent life is extremely difficult to emerge. Otherwise alien civilizations would necessarily be here. As a result we could find ourselves among the most evolved technological civilizations in our galaxy or we could even be the only one.

Besides these simple solutions there are many more exotic proposals[†]. For example, a rather drastic expansionist solution is given by the string theoretist Cumrun Vafa who thinks that the fact that we do not see aliens around could be the first proof of the existence of brane worlds: all advanced aliens would have emigrated to better parallel universes (our Universe would have zero measure) [7].

Recently we made our own proposal for solving the Fermi Paradox [8]. It states that, at present, all the typical galaxies of the Universe are already colonized (or large regions of them) by advanced civilizations, a small proportion of their individuals belonging to primitive subcivilizations, like ours. That is, we put forward the possibility that our small terrestrial civilization is embedded in a large civilization unknowingly and this situation should be common in all typical galaxies. Whether the primitive subcivilizations would know or ignore their low status would depend, most likely, on the ethical standards of the advanced civilization in which they are immersed. If the standards were low, the individuals of the primitive subcivilizations would be surely abused in many ways. Consequently, in this case the primitive individuals would be painfully aware of their low status. If the ethical standards of the advanced individuals were high instead, then very probably they would respect the natural evolution (social, cultural) of the primitive subcivilizations, treating them 'ecologically' as some kind of protected species. In this case, which could well describe the situation of the terrestrial civilization, the primitive individuals would be completely unaware of the existence of the large advanced civilization. Observe that the 'alien visitors', from the viewpoint of the primitive individuals, would not be so from the viewpoint of the advanced individuals because they rather would be visiting, or working in, their own territory. Observe also that we do not postulate that advanced alien civilizations might have strong ethical codes against interfering with primitive civilizations. We simply distinguish between aggressive and non-aggresive advanced civilizations, which in our opinion is a much more realistic idea. In this respect, the fact that our civilization has never been attacked by aggressive aliens, as far as history knows, could well be a clue that we belong to a non-aggressive advanced civilization which protects planet Earth, as part of its territory.

If this scenario were true for our civilization, then the *Subanthropic Principle* [8] would also hold. It states that we are not typical among the intelligent observers from the Universe. Typical civilizations of typical galaxies would be hundreds of thousands, or

[†]As many as fifty solutions to the Fermi Paradox have been collected in the book [6], although there are several left out which we mention in this article.

millions, of years more evolved than ours and, consequently, typical intelligent observers would be orders of magnitude more intelligent than us. Finally, in order for our proposal to be a solution of the Fermi Paradox, we complement it with an additional hypothesis, called the *Undetectability Conjecture* [8], which explains why we do not detect any signals of civilization from the outer space. This conjecture states that, generically, all advanced enough civilizations camouflage their planets for security reasons, because of the existence of aggressive advanced civilizations, so that no sign of civilization can be detected by external observers, who would only obtain distorted data for disuasion purposes.

3 The Fermi Paradox in the light of the inflationary and brane world cosmologies

3.1 Inflationary cosmologies

Almost two years ago Ken D. Olum argued [9] that in the infinite Universe predicted by eternal inflation there must be some large civilizations which have spread widely through the Universe and contain a huge number of individuals. Although the Fermi Paradox was not mentioned, the underlying idea was again that in the observable Universe, because of the existence of thousands of billions of stars much older than the Sun, there must be large civilizations much older than ours. Then the author presented some computations regarding the probabilities that typical intelligent observers belong to a large (galactic size) civilization at the present time. In particular, using the assumption of an infinite Universe, like in the models of eternal inflation, and doing some conservative computations he predicted that '*all but one individual in* 10^8 *belongs to a large civilization*'.

Dropping the infinite Universe assumption, but keeping still inflation, the author claimed that the predictions are not very different than for the previous case because inflationary models, even if not eternal, usually produce a Universe much larger that the Universe we observe. Then, invoking the anthropic premise that we are typical individuals, he predicted that there is a probability of 10^8 versus 1 that we belong to a large civilization, in conflict with observation. The author concluded: '*A straightforward application of anthropic reasoning and reasonable assumptions about the capabilities of other civilizations predict that we should be part of a large civilization spanning our galaxy. Although the precise confidence to put in such a prediction depends on one's assumptions, it is clearly very high. Nevertheless, we do not belong to such a civilization. Thus something should be amiss..... but then what other mistakes are we making.....?*' According to our proposal we could be part of a large civilization spanning our galaxy,

or a large region of it, without being aware, because of our primitive low status together with the high ethics of our hosts, as discussed in the previous section. The two major mistakes of the author, therefore, would have been to assume: first, that we are typical intelligent observers, and, second, that to belong to a civilization implies to be a citizen of it.

Olum's article seems to make the Fermi Paradox even stronger. However we do not agree with these views because, in our opinion, only our own galaxy matters for the problem at hand, regarding the observable Universe. Any other galaxies are much too far to be even considered as candidates for visitation or colonization in either direction (our closest neighbour Andromeda is more than two million light years away). As a result, it should not matter whether or not there is inflation or whether or not the Universe is infinite or finite, as long as inflation and the age of the Universe have little influence on the age of our own galaxy, in particular on the age of the Sun and the thousands of millions of stars older than the Sun. In other words, cosmological inflation affects the large scale structure of the Universe, but not the small galaxy-size scale, which is the only relevant scale for the spreading of civilizations. Otherwise one would have to postulate the existence of exotic phenomena, like wormholes [10], Alcubierre warp drive [11], Krasnikov tubes [12], etc., with the hope that they would allow intergalactic travel by advanced civilizations endowed with the appropriate technology. Our honest opinion, however, is that if this type of phenomena really existed, they could perhaps offer some practical help regarding interstellar travel in our observable Universe, but only *inside* our own galaxy.

3.2 Brane world cosmologies

In the last years brane world models have been of increasing interest for both Particle Physics and Cosmology. They put forward the possibility that our Universe is located in a subspace (brane) of a higher dimensional spacetime, with the standard model fields confined on the brane and gravity propagating in the bulk. This allows large, and even infinite, extra dimensions. Recent work on brane worlds started following the proposals of N. Arkani-Hamed, S. Dimopoulos and G.R. Dvali [13], and L. Randall and R. Sundrum [14]. The interest in these models comes from the fact that they offer the possibility to solve, or view from a newly different perspective, many longstanding problems in Particle Physics and Cosmology. First of all brane worlds may solve the hierarchy problem between the electroweak scale M_W and the Planck scale M_{Pl} without the need to introduce supersymmetry: M_W would be the only fundamental scale in nature, and the weakness of the 4-dimensional gravity would be just a consequence of the 4-dimensional graviton wave function being diluted in the bulk. But brane worlds can also shed some light on the baryogenesis and leptogenesis, on the proton stability, on the small masses and large mixing of the neutrinos, on the gravitational lensing (by brane world black holes), on the

nature of the dark matter and dark energy, etc. (see [15] for brane world reviews).

In contrast with the inflationary cosmologies, brane world cosmologies have the potential to truly strengthen the Fermi Paradox. The reason is that in the brane world scenarios our observable Universe is embedded in a much larger cosmos with, at least, one more large spatial dimension. Along the large extra spatial dimensions there may be other universes which could be parallel to our own, or intersecting it somewhere. If any of these scenarios turns out to describe the real world, then it would be natural to expect that some of these universes would have the same laws of Physics as ours and many of the corresponding advanced civilizations could master techniques to travel or 'jump' through the extra dimensions for visitation or colonization purposes. Moreover, one has to take into account that many of these universes could be very close to ours, even at less than one millimeter distance along an extra dimension. This opens up enormous possibilities regarding the expansion of advanced civilizations simultaneously through several parallel universes with the same laws of Physics, resulting in multidimensional empires. It could even happen that the expansion to other 'parallel' galaxies through extra dimensions could be easier, with lower cost, than the expansion inside one's own galaxy.

In many other universes, however, the laws of Physics would be different, corresponding perhaps to different vacua of the 'would be' ultimate Theory of Everything, resulting probably in 'shadow matter' universes with respect to ours. This means that shadow matter would only interact with our matter gravitationally, in the case it would be brought to our Universe using appropriate technology. This does not mean, however, that the shadow universes would be necessarily empty of intelligent beings. If some of them had advanced civilizations, some of their individuals could even 'jump' to our Universe, but not for colonization purposes since they would not even see our planets and stars, which they would pass through almost unaware (they would only notice the gravitational pull towards their centers). And the other way around, we could neither see, nor talk to, the shadow visitors, although they could perhaps try to communicate with the 'would be' intelligent beings of our Universe through gravitational waves, for example.

At present we are still in a very premature phase in the study of brane worlds and we do not know whether these ideas are in fact realistic. Nevertheless, the idea of large extra dimensions and parallel universes is acquiring greater and greater importance in the scientific community, among both theoreticians and experimentalists. As a matter of fact, the experimental signatures expected from large extra dimensions, at present and future colliders, are well understood by now [16] and an intense experimental search is currently under way. For example, experiments starting in 2007 at the LHC (CERN) will be looking, among other events, for signatures of large extra dimensions.

4 Conclusions and Final Remarks

We have discussed whether the inflationary and brane world cosmologies have the potential to influence the problem known as the Fermi Paradox. We conclude that cosmological inflation does not influence the spreading of civilizations through our galaxy, contrary to recent claims, since it does not affect the age of the stars in it. Even if inflation produces a much older, or infinite Universe, like in eternal inflation models, it will be only relevant at very large scales far beyond visitation or colonization by technological civilizations, unless one invokes very exotic phenomena able to connect distant galaxies efficiently enough with regards to space travel (possibility in which we, honestly, do not believe). Only in this case an older, or infinite Universe would increase the probabilities of visitation by civilizations of other galaxies in our observable Universe.

In the case of brane world cosmologies we conclude that some of these scenarios could have the potential to strengthen the Fermi Paradox, provided they involved parallel universes with the same laws of Physics as ours. Then it would be natural to expect the existence of advanced civilizations capable of traveling through extra dimensions for visitation or colonization purposes, in either direction. It could even happen that the expansion to other parallel galaxies through extra dimensions could be easier, with lower energetic cost, than the expansion inside one's own galaxy, since many of these universes could be very close to ours, even at less than one millimeter distance along an extra dimension.

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References

[1] C.H. Lineweaver, Y. Fenner, and B.K. Gibson, 'The galactic habitable zone and the age distribution of complex life in the Milky Way', Science 303, 59, 2004.

[2] I. Crawford, 'Where are they?', Scientific American, July 2000

[3] J.W. Deardorff, 'Possible extraterrestrial strategy for Earth', Q. J. R. Astron. Soc., 27, 94, 1986.

[4] W.I. Newman and C. Sagan, 'Galactic civilizations: Population dynamics and interstellar diffusion', Icarus 46, 293, 1981.

[5] R. Jastrow in videos of the series 'The Universe of Stephen Hawking', 1996.

[6] S. Webb, '*If the Universe is Teeming with Aliens.... Where is Everybody? Fifty Solutions to the Fermi Paradox and the Problem of Extraterrestrial Life*', Copernicus Books, New York, 2002.

[7] C. Vafa, private communication.

[8] B. Gato-Rivera, 'Brane Worlds, the Subanthropic Principle and the Undetectability Conjecture', physics/0308078, 2003.

[9] K. Olum, 'Conflict between anthropic reasoning and observation', gr-qc/0303070 version V1 (2003).

[10] M.S. Morris and K.S. Thorne, Am. J. Phys. 56, 395, 1988.
M. Visser, *Lorentzian Wormholes: From Einstein to Hawking*, AIP Press, Woodbury, New York, 1996.
M. Visser, S. Kar and N. Dadhich, Phys. Rev. Lett. 90, 201102-1, 2003

[11] M. Alcubierre, Class. Quant. Grav. 11, L73, 1994.
H.E. Puthoff, Phys. Essays 9, 156, 1996.

[12] S.V. Krasnikov, Phys. Rev. D 57, 4760, 1998.

[13] N. Arkani-Hamed, S. Dimopoulos and G.R. Dvali, Phys. Lett. B429, 263, 1998; Phys. Rev. D 59, 86004, 1999; Phys. Today 55N2, 35, 2002.

[14] L. Randall and R. Sundrum, Phys. Rev. Lett. 83, 4690, 1999.

[15] R. Maartens, Living Rev. Rel. 7, 1, 2004.
I. Antoniadis, Eur. Phys. J. C 33, S914, 2004.
C. Csaki, 'TASI lectures on extra dimensions and branes', hep-ph/0404096.
V. Rubakov, Phys. Ups. 44, 871, 2001.
D. Langlois, Prog. Theor. Phys. Suppl. 148, 181, 2003.

[16] G.F. Giudice, R. Rattazzi and J.D. Wells, Nucl. Phys. B 544, 3, 1999.
E. A. Mirabelli, M. Perelstein and M.E. Peskin, Phys. Rev. Lett. 82, 2236, 1999.
K. M. Cheung and W.Y. Keung, Phys. Rev. D 60, 112003, 1999.